gland. The cast-off cuticles are found toward the center of the knots formed by the mites while the adult individuals occupy the periphery, their heads being directed towards the bottom of the gland. He considers that the habits of the pig would render contagion easier than in other animals, and thinks that had the swine he examined not been killed, the result of the disease would probably have had as fatal an issue as is generally observed in the similar disease in dogs.

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THE GEOLOGY OF CENTRAL AUSTRALIA.

BY EDWARD B. SANGER.

THE geology of the great central basin of Australia has until recently been a matter of some uncertainty. From analogical reasons conclusions have been formed which are more or less correct. Still at best they were but shrewd guesses. Our knowledge has been of a limited kind. The various explorers who have ventured to cross the continent have seldom taken any scientific men with them. Hence the reports received from time to time of this *terra incognita* have been vague and conflicting. Australia nevertheless has had not a few advantages in its scientific history. Many men of science whose reputation is now world wide, first became known to fame by their work on Australian shores. But the attention of naturalists has been restricted, for the most part, to the east coast of the continent, while the remainder has been comparatively neglected. This, to a certain extent, was unfortunate, as the east coast possesses the novel Australian features in the least degree. It shares its peculiarities with other approximately well-known regions. Thus on the north-east coast there is a large intermixture of Asiatic characters. These are less marked as the coast is followed to the southward, but still there is a large proportion of forms belonging to the Pacific islands, New Zealand, &c. On the south coast, however, the case is different. Here the flora and fauna are peculiarly Australian. The physical differences between Sydney harbor and Melbourne are slight, but according to Tenison-Woods, the marine fishes are of different species. The geological structure of the south and east coasts also differs widely.

Taken in its totality Australia is built on the true continental model. It has the characteristic elevated borders and the de-

pressed interior. The highest border is on the east, facing the largest ocean, and it averages about 2000 feet in height. The south side is either level with the ocean or abuts upon it in cliffs varying from 300 to 600 feet in height. The western is about 1000 feet above the sea, and the northern a little higher. Australia is thus in the form of an immense table-land. The seaward side is generally precipitous, but narrow tracts of lowland sometimes intervene between the elevated region and the sea. The continent slopes gradually inland from the elevated borders to the central depression at Lake Eyre, which is south-east of the topographical center. The main cordillera of the continent forms the eastern border. It consists essentially of a central granitic axis with doleritic or dioritic dykes flanked by highly inclined Archæan and Silurian schists, Devonian rocks less inclined and altered, and the upper and lower coal measures. Over these lie the almost horizontal beds of the Hawkesbury series (Lower Mesozoic). It is generally conceded that this cordillera is of Palæozoic age, and was elevated at the close of that period. The western border, as far as is known, resembles the eastern.

Throughout the table-land are various isolated mountain ranges which do not extend for any distance. These ranges trend either nearly north and south or east and west. The largest of them is the Flinders, which begins at Cape Jervis on the south coast and extends to the south end of the Lake Eyre basin where it ends abruptly. West of Lake Eyre is a chain trending about north-north-east, consisting of two ranges, the Peake and Mt. Margaret. North-west of these, on the 26th parallel, is a large range, the Musgrave, which trends about east-north-east. North of this is another, the MacDonald, parallel to it. These are the main ranges, but isolated mountains of granitic base crop out in various places.

The south side of the continent is formed, with but little interruption, by a series of Tertiary rocks, representing probably all the formations from the Eocene upwards. They extend inland for at least 400 or 500 miles. The cliffs that abut on the sea in the Australian Bight are Miocene. The Murray River basin is also formed by Tertiary rocks of various formations. On the eastern and south-eastern coasts these deposits are overlaid either by volcanic emanations or by sands, clays and marls derived from the sub-aërial weathering of the Palæozoic rocks. The volcanic

deposits are Tertiary, and sweep around the eastern side from north to south, becoming more recent to the southward. Mt. Gambier and Mt. Schenck are volcanic cones which are situated near the southern limit of this disturbance. On the south side of the continent raised beaches are common, but are of limited extent. The great central depression, is, like the Saharan desert, of Mesozoic age. Its limits are as yet not strictly defined. Mesozoic fossils have been found on the east side all around the Gulf of Carpentaria, and I have found Jurassic fossils *in situ* 300 miles west of the overland telegraph line. Covering the Mesozoic beds in the interior are eolian deposits and drifts. On the north coast the Palæozoic rocks outcrop again and are overlaid unconformably by Mesozoic rocks. Such is the general structure of the continent.

The region which I intend to discuss especially is that lying between the south parallels 22° and 30°, and the meridians 130° and 140°.

The country contained within these limits comprises very nearly the known limits of the great central basin. How much farther it extends to the westward is a matter of doubt. If a vertical east and west section could be cut through this basin from the eastern cordillera across Lake Eyre and through the Peake range, the approximate position of the rocks would be as seen in the diagram:

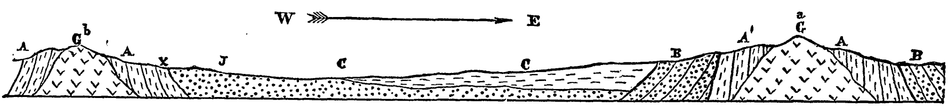


FIG. 1.—*G–G*, granite; *A–A*. Archæan schists; *A'–A'*, Archæan and Silurian schists; *B–B*, Devonian and Carboniferous; *C*, Cretaceous; *J*, Jurassic; *a*, eastern cordillera; *b*, Peake range; *c'*, Lake Eyre basin. *x*, outcrop of springs.

Now if a section were cut in a like manner through the Peake range on the east, in a north-westerly direction through the Musgrave range, we should have a section as seen in Fig. 2:

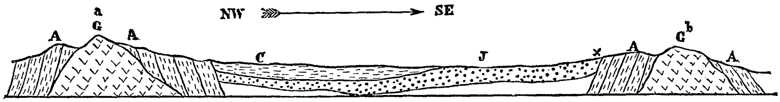


FIG. 2.—*G–G*, granite; *A–A*, Archæan, *J*, Jurassic; *C*, Cretaceous; *a*, Musgrave range; *b*, Peake range; *x*, outcrop of springs.

The Musgrave ranges at their base are about 3000 feet above the level of the sea; the Peake range 800 feet; Lake Eyre 300

feet; and the eastern cordillera 3500 or 4000 feet. Thus there is a gradual slope from the east and the west toward Lake Eyre. The Peake range, arising as it does, roughly divides the great basin into an eastern and western portion. It is worthy of remark that the Peake range is flanked by the Jurassic formation on each side, while the Cretaceous beds flank the ranges on the extreme eastern and western boundaries. There is evidence to show, however, that the latter beds are underlaid by Jurassic rocks. The Musgrave range consists of a central core of granite, flanked on either side by a great variety of gneissoid rocks much folded and inclined at a high angle. Many dykes of doleritic rocks cut through the metamorphic gneisses.

The granite varies greatly in character within short distances. The most common is a large porphyritic variety with a coarsely granular base. The orthoclase crystals often measure three inches in length. Mineralogically the granite is usually of the normal ternary kind, *i. e.*, consists of orthoclase, quartz and mica. The mica is almost invariably biotite. Sometimes oligoclase is found with the orthoclase, and often completely replaces it. In other localities the granite loses its quartz and mica, and those minerals are replaced by hornblende, the rock becoming a pure syenite. Then again in the syenitic form the orthoclase takes a subordinate place and is replaced by oligoclase. In this variety I have found small quantities of augite as an accessory mineral. These varieties of composition all occur in the same mass and may be stated as follows:

a. Normal.—Consists of orthoclase, quartz and biotite. Tourmaline often present in small pockets or nests.

b. Hornblendic.—Same as above but contains hornblende.

c. Oligoclase-bearing.—Oligoclase present and sometimes completely replacing the orthoclase.

d. Syenitic.—Hornblende replacing the biotite. Quartz quite or nearly absent.

e. do. Oligoclase-bearing.—Consists of hornblende and oligoclase. Is a dark gray. Resembles the rock called trachydolerite (Abich). Augite sparingly present as an accessory mineral.

The granite may thus be said to vary from its normal composition to a syenite. The normal rock is by far the most abundant. Next in order is the syenitic variety.

The gneissoid rocks flanking the granite vary as much in composition and physical characters as the granite itself. The most common kind is a light-gray coarse granular gneiss consisting of quartz, orthoclase and muscovite or biotite, sometimes both of

the micas. This normal rock passes on one hand into metamor phic granulite which has two varieties, one a fine-grained white rock containing a preponderance of quartz ; the other reddish and coarse grained, in which the orthoclase predominates. This again passes into a true metamorphic muscovite-granite. This is a light white-gray rock moderately fine in structure, and is very different in appearance to the granite forming the central axis. On the other hand the normal gneiss may become (*a*) *hornblendic*, in which case it generally loses some quartz ; (*b*) *garnetiferous*, containing crystals of almandite ; (*c*) *epidotic*, containing epidote (pistacite). The last variety passes into unakite, a very beautiful rock consisting of dazzling white quartz, reddish orthoclase and yellowish-green epidote ; and this again into pure epidosite by losing its feldspar. All these rocks alternate with each other, are much folded, incline generally at a steep angle, and strike north-east. I consider them to be of Archæan age ; or the slates and schists which form the Flinders range, and are probably Cambrian or Lower Silurian, strike north-west and are unconformable to the Peake and Mt. Margaret ranges, formations which belong undoubtedly to the same horizon as the Musgrave Range rocks.

The central granite is more recent than the Archæan gneisses, as it faults them and in places has partially re-metamorphosed them.

The dolerite rocks are probably more recent than the granite, and are as follows :

a. Dolerite.—Consists of augite, labradorite, magnetite, olivine and sometimes chlorite. Biotite is often present as an accessory mineral. In structure it varies from a granular crystalline to a jet-black aphanitic variety.

b. Norite.—A coarse dark reddish-gray rock, consisting of foliated pyroxene and labradorite.

c. Augite-Andesite.—A nearly black, fine, granular rock consisting of andesite and augite. The latter is often in distinct though small crystals, giving the rock a porphyritic structure.

The main dykes follow the strike of the metamorphic rocks, but innumerable cross dykes are given off which run in every direction. What the exact chronological place is for the granite and these rocks it is as yet, in the present state of Australian geology, impossible to say. About sixty miles south of the Musgrave range there is another range exactly similar in every particular, which is known as the Everard. The MacDonald

range to the north is also constructed on the same plan. In the Everard range the doleritic rocks are better developed, but occupy the same position and show the same variation in composition and structure. The two ranges are in fact counterparts of each other.

The Peake and Mt. Margaret chain has essentially the same structure, with the exception that the doleritic rocks are apparently wanting. The Archæan gneisses exist here in the form of crystalline schists, quartzites and limestones, and vary in character. The strike is north-east, and they dip to the north-west at a high angle. The schists are as follows:

Mica schist.—Contains both muscovite and biotite.
- *a.* Tourmalinic.
- *b.* Specular (Itabyrite) containing much hematite.
- *c.* Calcareous.

Hydromica schist.—Containing margarodite in place of the muscovite.
- *a.* Garnetiferous.
- *b.* Pyritiferous.
- *c.* Chloritic.

Chlorite schist.—Greenish-gray.
- *a.* Garnetiferous.
- *b.* Epidotic.

Hornblende schist.—Consists of quartz and hornblende. Sometimes wholly of hornblende.

Actinolyte.—A tough, light-green rock.

Intercalated between these beds of schist are strata of:

Quartzite.
- *a.* Feldspathic (orthoclase).
- *b.* Micaceous (muscovite).
- *c.* Tourmalinic.
- *d.* Hornblendic.

Hematite.—A dark red rock. Jaspery.
- *a.* Foliated hematite (micaceous iron ore).

Limestone.—Coarse grained, blue, clinking under the hammer.
- *a.* Pyritiferous.
- *b.* Graphitic.
- *c.* Micaceous.

Through these metamorphic rocks irregular masses of granite have been intruded, though not to so great an extent as in the Musgrave range. The granite is more hornblendic, but quartz is always present. It is much coarser in grain, and is porphyritic. Veins of orthoclase of considerable size are present in it.

Through the metamorphic rocks are also: (1) Quartz veins bearing much pyrite. Near the surface this has been oxidized,

and the quartz is cavernous. These veins follow the strike of the schists.

(2.) Faulting them are veins of calcite in which are found the following minerals: *Pyrite*, *chalcopyrite*, *malachite*, *bornite*, *galenite* and *selenite*. None of these minerals are present in any quantity. The calcite veins are seldom over six or eight inches in width, while on the other hand the quartz veins attain, in some places, a diameter of many feet. One in particular, situated near the foot of the range at the Peake telegraph station, stands up like a gigantic white buttress about fifty feet high, and is nearly eighty feet in width. Many similar examples could be given.

The next formation in age is that forming the Flinders range, which we have mentioned as ending abruptly south of Lake Eyre. It is probably Cambrian or Lower Silurian, but is so singularly destitute of fossils throughout its entire length, that no exact data, except from a lithological standpoint, are known. The rocks are schists, slates, limestones and quartzites. They are very different lithologically from the Archæan rocks; they strike north-west and are much folded and inclined at high angles. Metalliferous veins are abundant in them. The great copper deposits of South Australia are in rocks of this age. The ores are sulphides. Carbonates of copper are abundant, but have not as yet proved to be permanent. Gold is very generally found in the quartz veins which run north-west, following the strike of the rocks. The cross veins are not so rich. In the southern parts of the range there are large deposits of galenite, which is very generally argentiferous. Besides these minerals, deposits of bismuth, graphite, antimony and manganese are found, but are not worked. The Cambrian rocks in fact all over the continent are the richest in metalliferous lodes; although quantities of tin are found in the granite of the Queensland cordillera.

The Jurassic formation abuts unconformably against these Cambrian rocks at their northern termination. It is of vast extent, covering the whole of the central part of the great basin. Lithologically, curiously enough, it bears a striking resemblance to other deposits of the same age in various parts of the world, but notably in England and in the Western United States.

The beds are uniform in character and consist of compact gray shell-limestones, gypsiferous marlites, and sandstones. The limestone is fossiliferous and contains the following characteristic

forms: Monotis, *M. curta; Mytilus minimus, M. ingens*, n. s. (Tenison-Woods); Tancredia; Cytherea; *Lima gigantea; Cardinia listeri;* Pleurotomaria; *Cucullæa oblonga;* Avicula; Pecten; and Modiola. In the gypsiferous marlites are found many calcified Belemnites, *B. canaliculatus* and *B. densus*, but no other fossils, as far as I was able to ascertain.

The beds are generally horizontal, but in some places are slightly inclined. The inclined strata give rise to the low table-top hills mentioned above. About a hundred miles west of the Peake range there is a range of rough flat-topped hills trending north. These consist of eruptive felsite breaking through the Jurassic strata, partially metamorphosing and folding them, but only in the immediate vicinity of the eruption. The felsite is fine granular in texture, and varies in color from white to red.

A section taken near the outbreak of felsite shows the rocks in the following order, beginning at the surface: *a.* Sandstone conglomerate, cross laminated in many places; *b.* Gypsiferous marlite, containing Belemnites; *c.* Compact gray fossiliferous limestone; *d.* Compact ferruginous sandstone. This order of superposition is the same wherever I have seen the Jurassic beds in the interior. A cross section of the Peake range is as seen in Fig. 3.

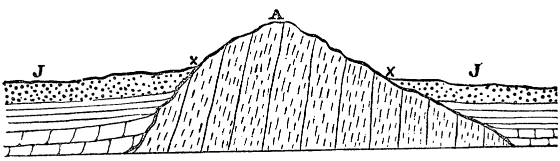


FIG. 3.—*A*, Archæan schists; *J*, Jurassic beds; *x*, springs.

The sequence of the Jurassic beds is the same as given above. At the Finiss springs these beds lie uncomformably against the Palæozoic rocks as seen in Fig. 4.

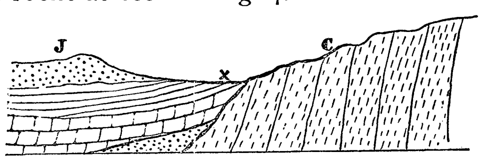


FIG. 4.—*C*, Cambrian; *J*, Jurassic; *x*, springs.

The beds do not vary lithologically, but the fossils are often absent. They seem to be distributed in patches. The compact sandstone in every natural section that I have seen is the lowest bed. Well borings, however, have shown that similar rocks un-

derlie them. What the thickness of the whole formation is, therefore, it is impossible to say. The thickness of the beds mentioned above is about 250 feet; in many places, however, some of the beds thin out and are wanting; this is notably the case with the fossiliferous limestone.

Lake Eyre lies south of the center of this great zone of rocks. They extend westwards probably nearly 300 miles. Then they sweep around the northern end of the lake and extend eastwards for about a hundred miles, as far as I have been able to ascertain. Circling around the northern boundary of the Jurassic beds and lying unconformably on them, where they overlap, is another series of rocks which varies greatly in character. In the north-west they consist principally of kaolin beds, sandstones and limestones. The kaolin beds are the best developed, and are undoubtedly derived from the masses of eruptive felsites mentioned above. These beds flank the Musgrave and Everard ranges and extend north an unknown distance.

The kaolin varies from a pure white, unctuous clay to gritty and indurated siliceous varieties of different colors. The finer kinds are very abundant. One in particular, known colloquially as the "Charlotte Waters' meerschaum," is a beautiful soft white variety. The Charlotte Waters telegraph station is built of it. Neither the kaolin nor the beds associated with them (sandstones and limestones) are fossiliferous, but eastwards they are continuous with beds resembling the Jurassic lithologically, but containing true Cretaceous fossils. So it is presumable that they belong to that age. To the north-east and east the Cretaceous beds extend to the Gulf of Carpentaria and some distance into Queensland. They consist here principally of sandstones and gypsiferous marlites containing Ammonites, Belemnites, Trigonia and remains of Ichthyosaurus.

South-east of this great Mesozoic basin lies the immense basin of the Murray river. The latter is covered with Tertiary deposits and is separated from the former by outcrops of the Cambrian rocks. The Mt. Poole and Mt. Browne range, about sixty miles south of Burke's grove at Innaminka, consists of these rocks and auriferous quartz veins are being worked there at present. Over the Cretaceous and Jurassic beds lie recent drifts and æolian deposits. The greater part of the continent, in fact, is covered with such formations, and as they are so extensive and important, I will write of them in detail.

They are of two kinds, sand drifts and stony drifts. The sand consists of rounded grains of quartz, and is arranged in long low ridges. Between these ridges are open clay-flats or "clay-pans" formed of a yellow or reddish clay. Both sand and clay have been derived from the slow sub-aërial weathering of the granite and crystalline schists which form the ranges. Near the latter the sand contains grains of feldspar, zircon, tourmaline, magnetite and hematite. But further away it consists of pure quartz. The feldspars decompose and form the basis of the clay and the various salts with which it is impregnated. (See infra.)

The sand hardens into a sandstone showing much cross-bedding and oblique lamination, as might be expected from its aërial origin. Through the rock are ferruginous bands in which are carbonized remains derived from surface vegetation. The denudation of this sandstone gives rise in part to the cliffs and table-topped hills so characteristic of Central Australia. Throughout the continent such deposits are now forming but similar conditions have produced the same formation at other epochs. Thus in New South Wales such a sandstone is found many feet in thickness, and containing remains of ferns and cycads. They lie unconformably on the Permian and Liassic coal-beds, and evidently belong to the Lower Mesozoic. In Queensland they overlie the Cretaceous beds and, according to Tenison-Woods, are Tertiary. In the interior basin there is a complete gap between these beds and the Mesozoic rocks. They, as we have said, are forming at the present day, and probably have been so doing ever since the Mesozoic beds arose from the sea. The plant remains of the beds in the interior, as far as I have examined them, are not preserved well enough for identification. But here and there throughout the interior are found remains of the gigantic marsupials — Diprotodon, Nototherium and Phascolomys. These animals probably lived in the latter part of the Tertiary and early and middle Quaternary.

Alternating with the sand deposits are plains composed of stony drift. This is, for the most part, derived from the destruction of the æolian sandstones in their turn. In other cases, however, near the confines of the desert, wherever the crystalline rocks outcrop, it is derived from them. The boulders and pebbles lie thickly strewn on the surface, and are stained a dull red from the presence of the oxide of iron. It is owing to this col-

oration that the region covered by such deposits are known colloquially as "redstone plains." The drift is often many feet in thickness, and contains silicified wood and casts of existing land and fresh-water shells. It is being, and has been, formed synchronously with the æolian sandstones, and in many places the latter merges indefinably into the stony drift.

Following the course of the many dry watercourses which intersect this region, are immense deposits of alluvium. Two distinct formations can be recognized; an older and much the larger, and a smaller recent one. The lower formation consists of beds of sand, gravel and clay. The stratification varies from the most regular deposits to beds showing oblique lamination and flow and plunge structure. These deposits extend some distance on each side of the watercourses, and vary greatly in thickness. It is in these beds that the most abundant remains of the extinct marsupials are found. They extend laterally far beyond the limits of the more recent deposits which overlie them. The latter consists of fine-grained, thin-laminated alluvium. It contains no remains of Diprotodon, &c., but existing fresh-water shells such as Anodon, Paludina, Physa, &c., are abundant. It is formed by the deposition of sediment which the periodic floods bring down. Such, as far as is now known, is the structure of Central Australia.

At the close of the Archæan age the rocks which we have described as belonging to that age, were crystallized, folded and raised above the surface of the primeval sea, forming islands which probably have not since been completely submerged. After this elevation followed an immense period of quietude, during which vast beds of sediment derived from the erosion of these rocks, were deposited in a Palæozoic sea. Then at the end of the Cambrian or Silurian period another elevation occurred, and the rocks forming the Flinder's range were crystallized and upheaved. As I have said, at the northern extremity of this formation the Mesozoic rocks lie unconformably on it; so that there is a complete gap between. It is probable, however, that the Mesozoic beds are underlaid by Devonian and Carboniferous deposits. The structure of the eastern border region lends probability to this view. At any rate the whole lapse of time between the upheaval of the Cambrian or Silurian rocks until the close of the Jurassic, must have been, in the interior basin, a period of

slow oscillation and general quiet, during which beds of sediment were formed slowly at the bottom of the sea. At the close of the Palæozoic the eastern border and perhaps the western was elevated, thus forming an interior sea and foreshadowing the form of the continent. Another period of repose then followed until at the close of the Jurassic a large disturbance occurred. Land slowly emerged from the central part of the sea around the island of Archæan rocks now known as the Peake range. Contemporaneously with this upheaval vast floods of felsite were poured out through a line of fracture trending north and south on the western boundary of this region of elevation. Then came another period of rest, during which the waves and currents of a Cretaceous sea worked away at these new rocks. On the west side vast beds of kaolin were formed, derived from the felsitic rocks. In the remainder of the sea the conditions were much the same as in the Jurassic period, and similar beds were formed. But the fauna shows a gradual change in the life dwelling in the seas, as might be expected.

Finally, at the end of the Mesozoic age, the whole of the interior basin was elevated above the sea, and though minor changes of level have occurred, has remained above ever since. During all these changes of level the southern portion of the continent had not yet appeared, except the southern extremity of the Flinder's range. But since the Miocene period the southern part of the continent was raised above the sea. Either contemporaneously or subsequently there was a large amount of volcanic disturbance. After this there was a subsidence, as is seen by the fringe of æolian sandstones which, for a short distance out to sea, surrounds the southern coast.

During Tertiary times there was a subsidence along the eastern border. According to Tenison-Woods there is a long fault at the edge of the Blue mountains, and for many miles north and south there is a down-throw which brings the Hawkesbury sandstone (Mesozoic) nearly to the level of the sea, where it forms the fiords and diversified scenery of Port Jackson and other parts of the eastern coast. The existence of the Great Barrier reef indicates a period of slow subsidence on the north-east coast during Tertiary times. The western coast seems to have also participated in the general upheaval at the close of the Miocene, as raised beaches have been noticed there. The interior basin has

probably been dry land since the close of the Mesozoic ; at least there is no evidence of its having been submerged. As the land arose the rate of elevation varied, occurring more rapidly in some places than in others. Consequently the interior sea would be changed first into an archipelago and this changed slowly into dry land, containing small inland seas, which gradually became large lakes such as Lake Eyre, Torrens and Gairdner. During the early half of the Quaternary the climate was moister, and consequently was better adapted for animal and vegetable life than at the present day. That it was the case is shown by the greater thickness and structure of the lower alluvial deposits, and also by the bones of the great marsupials found in them. These animals must have had a more luxuriant vegetation to feed upon than now exists. The climate probably, through the elevation of the southern border and other causes, gradually became more and more arid until it reached the present stage. The giants of earlier days have passed away, and strangely enough, as if nature delighted in abrupt antitheses, they are replaced by some of the smallest forms of the order of animals so characteristic of Australia.

Although the whole of this region is remarkably arid, the surface is intersected by innumerable watercourses which, though dry for the greater part of the time, periodically are filled by flood-water from the ranges. In the eastern part of the basin these creeks arise on the slope of the Queensland cordillera and flow westerly into Lake Eyre. From the north-west flow the Peake, Neales and others. Smaller creeks flowing in the same general directions are abundant. They either die out altogether or unite with the larger ones, or end in the salt lakes so common throughout the region. The salt lakes are generally but little more than large clay-pans where the water has periodically accumulated and then evaporated, leaving a deposit consisting of various salts. Some, however, are larger, and like those I have mentioned, are true lake basins. The true lakes are never I believe, completely dry, but the water becomes very low and intensely salt and bitter. Every flood as it comes down spreads out on the flats bordering the creeks, and extending laterally, in some places several miles, quickly evaporates, leaving a deposit of earthy sediment, and finally a thin deposit of the salts. This process is repeated time and again until considerable beds are formed. If the flood

is a large enough one the water finally finds its way to the large lakes (principally to Lake Eyre). These lakes, if the flood is very heavy, become tolerably fresh, and stay so until through loss of water by evaporation (none of them have outlets) the water again becomes salt. As evaporation proceeds the water slowly recedes, leaving a dazzling white incrustation, and sometimes a layer of dead fish which have been brought down by the flood, and when the water became too salt have been compelled to succumb.

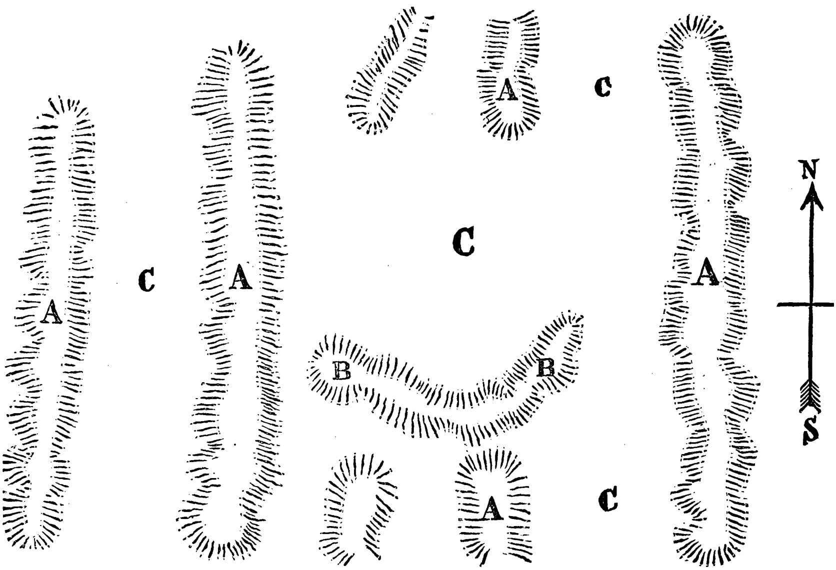
The lakes and clay-pans accordingly, unless seen in flood time, are generally a painfully white plain fringed by a few sickly Acacias. The salts are of different kinds; the most abundant one deposited is sulphate of lime (gypsum). The general form of crystallization of this salt is the common monoclinic twin or arrowhead crystal. Often, however, it is found in large transparent slabs and in a fibrous state. The next in importance among the salts are the carbonates of lime, magnesia and soda; the chlorides of sodium and magnesium, and the sulphates of magnesia and soda and iron. All these are derived from the decomposition of the rocks forming the ranges from whence the watercourses arise and from the denudation of the outcrops of the Mesozoic rocks which underlie the whole region. The actual amount of rainfall on the eastern and western slopes of the basin (especially the eastern) is largely in excess of the drainage by the watercourses, so there must be a large portion which soaks into the ground and drains away along the incline towards the interior, where it accumulates under great pressure. That this is the case is shown by the existence of a line of cold and thermal springs that extends north and south through the central basin. That the water comes from a great depth is evident from the fact of their temperature and the mounds of travertine they have built for themselves. The overland telegraph line nearly follows the line of outcrop of these springs. This line is also the outcrop of the crystalline schists forming the Peake range. Another line of springs extends in an east and west direction and follows the overlap of the Mesozoic rocks upon the Palæozoic schists of the Flinders range. The explanation is simple. The water coming from the north-west and north-east flows along down the inclines toward the central basin until it meets with a barrier in the schists of the Peake range. It cannot pass through them, and

accordingly it is forced to the surface by hydrostatic pressure. Consequently there is a double line of springs following the outcrop of the schists (see figures *ante*). A great deal of the water flows on further south until it is obstructed by the Palæozoic rocks of the Flinders range, whereupon it comes to the surface, forming an east and west line of springs (see Fig. 4). The quantity of salts contained by the water varies a good deal, but is always considerable. The principal salts are the carbonates of lime and magnesia. The travertine deposits are immense, and in some places form hills 200 feet high. The general form of the hills is that of a truncated cone. On the summit is a clear basin of water fringed with rushes, and down one side a stream of bright clear water trickles, soon to be re-absorbed by the parched ground. Bubbles continually rise to the surface of the pool, and are generally caused by the liberation from the water of carbonic acid gas. In other cases it is marsh gas, derived by the decomposition of the vegetable matter in the pool. When the water issuing from a spring has built a mound up to a considerable height, the pressure not being great enough to force it any higher, the travertine forms over the top, closing it completely, the spring then breaks out anew near its base. Mounds can be seen in every stage of evolution, from one the size of a bee-hive to one long deserted by water, standing alone like a huge melancholy sentinel. In these mounds are found remains of Diprotodon, &c. The conclusion is plain that an abundance of water could be procured by artesian borings through the rocks occupying the central desert, and possibly in this way the country may be developed in the future.

The topography of the interior is dismal and monotonous to a degree. In every direction from Lake Eyre the land gradually rises. The sandhill country predominates around the lake, but occasionally there are patches of stony plains. Both the sandhills and the intervening clay-pans are sparsely covered with low thickets or " scrub " of Eucalyptus, Acacia, Melaleuca and Cryptandra. Along the watercourses a few stunted gum trees are found (Eucalyptus). The stony plains, though a little diversified by the table-topped hills, are even more desolate in appearance. From north to east from the lake this is the character of the country for hundreds of miles. Ridge after ridge of sandhills covered with sparse vegetation, with here and there a dry clay-

pan or salt lake glistening painfully white under the fierce sun; no animal life save a few kites (*Milvus affinus* and *Elanus scriptus*), the never-absent crow and mayhap a forlorn sandhill wallaby (*Bettongia grayi*), and the deceitful mirage making everything seem weird and unreal. Such is the sight that greets the unhappy traveler until his eyes grow weary and his heart grows sick, yearning after cool streams and shady places.

The table-topped hills are generally derived from the erosion of outcrops of the Cretaceous and Jurassic rocks; in other cases from the compact æolian sandstone. The sandhills trend nearly north and south, generally a few degrees east of north. They show the true sand-drift structure, and have a sloping and an abrupt side. The direction of the trend is uniform over large areas.



A–A, parallel sandhills; *B–B,* crescent sandhills; *C–C,* clay flats.

If a sandy flat, to which the wind has free access, is examined, it will be seen that the sand has been blown into a series of ripples or ridges, whose long axes are at right angles to the direction of the wind, and on examining them closer it will be found that the side towards the wind is sloping and the opposite abrupt. Here then we have in miniature the sandhill country. The prevailing winds throughout the region are westerly and north-westerly, and the ridges trend at right angles with their sloping sides facing to the west or north-west. Where there is a decided variation in

the direction of the wind the sandhills also vary. The drifting sand has been arrested in its course by the bushes and other vegetation, and thus the sandhills have been gradually built up, although they have often been cut away and re-deposited, thus giving rise to the irregular position of their layers. Such is the general surface formation of the sandhill country, but here and there among the parallel ridges are solitary crescent-shaped sandhills whose long axes are at right angles to the prevailing system of hills. Facing the concave side of this variety of sandhills there is always a clay flat, at the other end of which the parallel sandhills re-commence, as seen in the sketch.

In the above sketch the concavity of the sandhill *B–B* is shown facing to the north; quite as often, however, they face to the south. The clay flat is always opposite to the concave side. These sandhills are usually several miles apart. What their origin is I cannot say. They possess the same structure as the normally built ones. It is possible that they may be the remains of another system of sandhills which by an alteration of climate producing a great change in the general direction of the prevailing winds, have been swept away and a new system formed. But if this is the case, why the crescent shape and why the variation of position among them? They have certainly not been formed by water, nor has their shape been modified to any great extent by its action, for if that was the case some traces would be left. And besides they are generally situated among the sandhills far away from any watercourse. There must be some cause for their existence. What that cause is I must admit is a mystery to me. I think the subject worth investigation, for it is certainly remarkable that there should be these anomalous cases scattered here and there through a region unique for its uniformity.

In the north-western portion of the basin, where the Cretaceous beds of kaolin occupy the surface, denudation has worn the soft clays into a great variety of fantastic shapes. Minarets, castles, temples and even grotesque images of man and beast are replicated on every hand in the greatest variety of dazzling colors. These are every shade from jet-black to snow-white. Gorgeous purple, delicate pink, rose red and somber brown, green and blue are mingled together with amazing confusion and prodigality. It is a riot—a mad dance—a very *carmagnole* of color. It would seem as if some mischievous elves had been rioting in nature's

color-laboratory and then affrighted by their pranks had fled, leaving all this splendor blazing unknown under the fierce sun of the desert—for a desert it is in everything save color. The Arkaringa creek, which arises in the Musgrave range, in its southerly flow has cut itself a passage through these beds. On each side are cliffs 400 or 500 feet high wrought into the strangest of shapes and bedecked with the gaudiest colors. It seems as if nature wished to show what she could do when she took the artist's tools in her own hand. But the lesson is lost, for few mortal eyes, save now and then a wandering black fellow, more intent on hunting lizards for his dinner than æsthetic worship, have ever beheld this gigantic sport of Dame Nature. But the eye tires of it, and soon is fain to turn for rest to the somber black-green of the scrub foliage. With the exception of this brilliant tract all the rest of the interior consists of the dullest and most prosaic country; sandhills and stony table-lands *ad nauseam.*

Such is a brief and necessarily imperfect description of the great Australian desert. We can see that Australia, though often called paradoxical, is not so, but conforms to the laws of continental development. The outlines of the continent have existed from the earliest times, and the whole has gradually been built up, step by step, until we find it as at the present time. There has been no paradoxical break in nature's handiwork nor in her laws. We see here the same grand, impassive uniformity, the same disregard for time that ever characterized her work, whether it be the molding of a germ of life, the elevation of the Alps or the creation of a solar system. Future researches may amplify the conclusions drawn in this paper, but the main facts will remain unaltered.

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THE NUMBER OF SEGMENTS IN THE HEAD OF WINGED INSECTS.[1]

BY A. S. PACKARD, JR.

BY a study of the structure of the head of adult insects it is very difficult, if not impossible, to determine the number of segments in the head of winged insects. The number as given

[1] Extracted from the forthcoming third report of the U. S. Entomological Commission.